the part lying in the plain is partly obliterated, as though it had been worn away by the action of water. In some it is almost entirely wanting, leaving a sort of semi-circular bay. We can hardly resist the conclusion that we here see the effects of the erosive action of water, in the times when there were yet sea. There are objects of interest in profusion for one possessing a moderate sized telescope.

The orbit of Mars is next outside that of the Earth. The mean distance of Mars from the Sun is 141,500,000 miles. Because its orbit is such a flattened ellipse, at times it is only 35,000,000 miles from the Earth ; again, when on the other side of the sun, it may be over six times as far away. Its journey around the sun is performed in 686.95 days. Its diameter is 4,200 miles. Its rotation upon its axis takes 24 hours, 37 minutes, 22.73 seconds. It may be distinguished from the other planets by its decidedly red tint.

In 1877, Prof. Hall, with the large Washington telescope, discovered that Mars has two satellites. One revolves about 4,000 miles from the surface of the planet, in a period of 7 hours, 39 minutes ; the other at about 12,500 miles, in 30 hours and 17 minutes. They are very small, among the smallest bodies in the solar system, probably not exceeding 20 miles in diameter.

Except when Mars is at its nearest opposition, and with favoring conditions, it is a rather unsatisfactory object with small telescopes. Yet, with such instruments the spots may be unmistakably seen. Observations on this planet, even when the best instruments are accessible, are rather contradictory, as far as details are concerned.

Its ruddy color is seen to be caused by the color of the continents, and has been thought by some observers to

be due to the color of the soil, by others to red vegetation, or both. The nature of the so-called seas is yet a matter of doubt; they are said to appear more like an uneven country through the Lick telescope, and the straight lines were not seen, and the alleged signal resolved itself into a mountain peak.

There are unquestioned features resembling those of our planet; the seasons, the atmosphere, the clouds, the ice-capped, polar regions, with the presence of water. The aqueous vapor no doubt accounts for many discrepancies in observations. It is evident that seas, continents and canals would be often obscured by the clouds.

With the optical difficulties attending the atmosphere of the Earth, augmented by another atmosphere,—that of Mars, negative testimony loses much of its weight, and the positive evidence of those skilled observers who have seen appearances indicating the presence of a system of "canals," cannot be ignored. Whether these or any other observed features are artificial or not, remains to be proven.

Taken all together we must regard Mars as probably an inhabited world, and very similar to the Earth. The area of its seas is much less than those of the Earth, and its habitable land surface lying mostly in and near the equatorial zone, has nearly as great possibilities of population, notwithstanding the smaller size of the planet.

Its seas are very likely reduced in extent from their former limits by the absorption of water, for Mars is farther advanced toward planetary old age than the Earth. If there were parts of old ocean beds already dry, it would tend to reconcile some conflicting observations.

It is a legitimate presumption that Mars reached its habitable stage long before the Earth was fitted to sustain life, and therefore its present inhabitants have had

a longer period in which to develop. Let us trust that they have long since outgrown creed and greed, and the inequalities, intolerance, persecutions, oppression, wars and suffering that arise therefrom ; if so, there would be hope for us.

Between the orbits of Mars and Jupiter there is a ring of minor planets called Asteroids, of which some 400 have been discovered. The first to be discovered were Ceres, diameter 569 miles ; Pallas, diameter 273 miles, and Vesta, diameter 237 miles. All are small, and their orbits near each other, and averaging about 250,000,000 miles from the Sun. When nearest to the orbit of Mars one of these little bodies comes within about 21,000,000 miles of it.

The theory was early advanced that these Minor Planets were fragments of an exploded planet of considerable size ; but it is questionable about this being the true explanation.

It seems probable that they have naturally formed from rings of nebulous matter, or of meteorites, revolving around the Sun. This view is strengthened by the now conceded fact that the rings of the planet Saturn are composed of an innumerable number of minute solid bodies. Doubtless many more of this group remain undiscovered.

Passing on to the distance from the Sun of 478,000,000 miles we come to the path of Jupiter, the largest planet of our system. His diameter is 87,000 miles ; period of revolution 4332.58 days ; mass 300 times that of the Earth, and its volume 1,300 times greater. Its density is about the same as that of the Sun ; nearly one-quarter that of the Earth. It rotates on its axis in the short period of about 9 hours and 55 minutes.

To the naked eye, Jupiter is only second in brightness

to Venus. It can be readily identified by the four bright satellites, visible with almost any little telescope. An ordinary telescope will show its disk flattened at the poles, and will also show broad, tinted belts across the disk parallel with the equator. These belts are evidently clouds, drifting and irregular, stretched along in line with the planet's rapid rotation. The belts are usually described as red, sea green, brownish, coppery, pale blue, brick-red, yellow, green and purple; the ruddy tints predominating, especially near the equator. In 1879 a great red spot appeared, remaining for years. It is supposed that here as in the Sun the equatorial masses of vapor revolve faster than those nearer the poles. It is evident that the denser body below is seldom seen, whether through the darker or lighter portions of the vapory envelope. Perhaps it was seen partly unveiled in the great red spot.

Jupiter and his four large moons look like a miniature solar system when viewed with low powers. The fifth satellite, discovered by Prof. Barnard with the Lick telescope, can only be seen with fine instruments.

The first satellite revolves around Jupiter in 1 day, 18 hours, 28 minutes, and is 2,450 miles in diameter. The second revolves in 3 days, 13 hours and 14 minutes, diameter 2,045 miles. The third revolves in 7 days, 3 hours, 43 minutes, diameter 3,558 miles. The fourth in 16 days, 16 hours and 32 minutes, diameter 3,345 miles. The fifth has a period of revolution of 11 hours and 57 minutes, its distance from the surface of Jupiter is 67,000 miles, from his centre 111,910 miles, and the satellite is over 100 miles in diameter. The measurements are given as determined by Prof. Barnard with the Lick refractor. The mean distances from their primary of the four large satellites are I. 259,000 miles,

II. 414,000 miles, III. 647,000 miles, and IV. 1,164,000 miles. All the satellites have a greater mean density than Jupiter. The satellites are frequently occulted by the planet, and they are also often seen in transit as bright round spots. Again the shadows of the satellites may be seen black and round crossing his disk, or the satellites may suffer eclipse by passing into the shadow of the great planet.

The third and fourth satellites as seen by Prof. Barnard, in the 36-inch Lick refractor, show large diffused markings, and white polar caps exactly like those of Mars. These observations by Prof. Barnard go to sustain the theory that the satellites of the large planets are near to, or passing through, their period of habitability. If the polar spots are due to ice and snow, as they are presumed to be in the case of Mars, and there is no reason to doubt it, then these satellites have atmosphere, and aqueous vapor. The white caps being confined to the polar regions, shows the temperature to be high enough to sustain life. A presumption is therefore raised that they are inhabited worlds.

CHAPTER IX.

THE SOLAR SYSTEM, CONCLUDED.

SATURN, shining with about the brilliancy of a star of the first magnitude, may be recognized by his pale steady light. Any one whose anticipations have not been unduly aroused by fine pictures of the planet, when viewing it for the first time with the telescope, will not fail to feel pleasure and admiration. It is a grand telescopic object. The globe itself shows very much like Jupiter, only smaller, paler, less flattened at the poles, and the belts less distinct. There have been spots of sufficient permanency to enable the rotation to be approximately determined, but as is the case with Jupiter, it is probable that no vision has ever penetrated the deep layers of vapor.

The superb system of rings by which the globe is environed, is unique in our planetary system. They are not indistinct and nebulous, but shine with the pale lustre of the body of the planet. A view through a moderate telescope, of the planet, his rings when open, and his eight satellites, or as many of them as may be visible at the time, is well worth a journey to see, and when rightly understood, will convey a most instructive lesson.

The average distance of Saturn from the Sun is 884,000,000 miles, its mean diameter is 71,000 miles, and it rotates on its axis in about 10 hours and 14 minutes. Its year is equal to 29 and 1-2 earthly years. Its density is only one-eighth that of the Earth.

There are three principal rings ; the one on the outside is about 150,000 miles in diameter. Minor divisions have been seen in all the rings. They were for a long time supposed to be solid, but a portion of the body of the planet has been seen through the inner ring. They lie in the plane of the planet's equator, are very wide and extremely thin, and it has been demonstrated that they could not maintain their positions if solid, and it would be at least doubtful if they could were they liquid or gaseous. This difficulty would be removed if they were assumed to be composed of small particles, or meteorites, and the spectroscope confirms this view. The planet itself is lighter than water, and is still at a high temperature, as was our earth many millions of years ago.

We have then in the Saturnian system several stages of world growth in the same field of view in our telescope, and all confirming the hypothesis that furnishes the only natural explanation of their existence.

The satellites are named Japetus, Hyperion, Titan, Rhea, Dione, Tethys, Enceladus and Minas, and their orbits are nearly on the same plane as the rings. Titan is the leader, and as measured by Prof. Barnard is 2.523 miles in diameter, and is 5.2 times as dense as Saturn. Titan revolves around its primary in 15 days and about 23 hours, at a distance of 781,000 miles from the centre of the planet.

To the inhabitants of these satellites, if any there are, their nocturnal sky must offer a spectacle of wonderful beauty and grandeur.

At one stage in their intellectual development the inhabitants of Titan must have held that their little moon was the fixed and solid center of the Universe, created for them ; and Saturn and his other attendants, (a resplendent retinue,) and the mighty rings, the Sun,

planets, and the "stars also," were made to give them light. Could they not see them, all these hosts, with their own eyes, revolve once in each of their days around their home? Such was the thoughtful care of the unknown being they worshipped. They were zealous to persecute and torture the poor heretics who dared to deny it, and to affirm that the phenomenon was due to the rotation of their own tiny moon. Of course it took a man-like god to plan and construct such a mechanical Universe. This belief came to be the foundation of their religion. Often pernicious effects continue long after the initial causes are removed. Religions, profitable to a ruling class, die hard; they have nine lives. The cosmogony and theology of the Titans were just as reasonable as those of the ancients we revere. Even in this advanced age of Titan they may continue to willingly pay from their hard earnings—means to be used to perpetuate their own follies and fears. This is indeed to kiss the rod that smites them.

The supernatural has a place in the line of evolution, but it is low down toward the foot.

Uranus, the next planet to Saturn, barely visible to the naked eye, was not known to the ancients. It was discovered in 1781, by Sir William Herschel, with his great reflecting telescope. Its distance from the Sun is 1,781,900,000 miles; diameter about 31,000 miles; sidereal period about 84 years; volume 65 times the Earth; mass 14.7 times the Earth, and its density 0.22 that of the Earth. Little has been learned about it by telescopic observation, and its period of rotation is unknown.

Herschel thought it was attended by six satellites, but only four are positively known. Their orbits lie at right angles to the path of the planet; the only instance

of the kind in our system. They are also said to revolve in a retrograde direction. The Lick telescope proves the rotation of the planet by showing that it is flattened at the poles. The eccentricity of its orbit is considerable, the greatest distance exceeding the least by 163,000,000 miles. Huggins, from spectroscopic observations, suspects the presence of large quantities of hydrogen in the planet's atmosphere.

Neptune is the most distant planet of the solar system, yet discovered. Irregularity in the movements of Uranus led M. Leverrier, in France, and Mr. Adams, in England, to independently inquire into their cause. Each arrived at the result that the perturbations were caused by the attraction of an unknown planet, and indicated its probable location in the sky. Leverrier communicated the result of his calculations to Dr. Galle of Berlin, who discovered the planet with his telescope within a degree of its calculated postion. The mean distance of Neptune from the Sun is 2,791,000,000 miles; its diameter is about 33,000; its time of revolution around the Sun about 165 of our years; its mass 17 times that of the Earth; its volume 85 times and its density 0.20 that of the Earth. It is known to have one satellite, supposed to be the largest of its class. Nothing is known of its rotation. The eccentricity of its orbit is less than that of any other planet, excepting Venus and some of the minor planets.

Comets have been until,—well, perhaps this century, the innocent cause of no little fear and superstition. They were looked upon even by the learned, up to a few centuries ago, as of baneful effect,—the harbingers of war and pestilence. It is only recently that astronomers have begun to understand their nature. Comets, like eclipses, have inspired the ignorant with abject

fear. Even Josephus believed a comet to be an omen of the destruction of Jerusalem. Such notions do not seem so absurd to those who, knowing little of nature's ways, habitually ascribe almost every phenomenon they may be unable to explain, to supernatural agency. Almost anything was easy to people so credulous as to believe that the Earth ceased to rotate, or turned back. (Sun stood still for nearly a day for Joshua, and the shadow returned ten degrees on the dial of Ahaz to convince king Hezekiah,—Bible.) Weigh all things, carefully, with the steadiness of courage, and with an even balance.

The work of science in clearing and making easy the paths for unwilling and faltering feet has been Herculean ; but it has been and now is a labor of love.

Conspicuous comets are not common, but nearly every year several telescopic comets are added to the list. The number of these wanderers that have passed around the Sun has been estimated at thousands and even millions. In searching for remote comets, or in examining large ones, the larger aperture should be used and the lowest eye-piece.

Comets vary greatly in size, brilliancy, length, and shape of tail, rapidity of motion, etc., and the same one may change perceptibly in a few hours. They are very light ; their attraction not being sufficient to cause perturbation when they pass near the planets. The orbits of several have been computed, while others are of long or unknown periods, if indeed they ever again visit our system.

Their tails develop as they approach the Sun, pointing away from that luminary. After its perehelion passage, which is very rapid, the tail of a comet will still point away from the Sun. The tail seems to be driven

away from the nucleus and its envelope by some repulsive force of the Sun. A force that as we might say discriminates, attracting the heavier, perhaps solid, nucleus, and the inner part of the envelope, while repelling the lighter material of the outer part of the envelope, and the tail; as though there was an outgo of one form of solar energy, and an intake of another answering to gravitation. Some think that there is electrical repulsion in this case.

Stars may be seen shining unaltered through the tails of comets, or even through the heads quite close to the nuclei. Comets are therefore composed of extremely attenuated material.

The testimony of spectrum-analysis seems to prove them to be swarms of small meteorites. This would accord with the observations showing them to shine in part by reflected light, and the collisions of the particles would develop some luminosity.

Halley's comet, a very bright one, has appeared several times, its last appearance being in 1835. Its period is about 75 years, and it will be next due in 1910. Encke's comet has an orbit nearer the Sun than Jupiter's, and a period of revolution of only about three and one-third years. Biela's comet has a period of six and one-half years. The celebrated comet of Donati, that appeared in 1858, will be again looked for in about 2,000 years.

The comets that either move in parabolas, or in very elongated orbits often pass close to the Sun; some perilously so. They seem to come from outside our planetary system. They are generally of great beauty and brilliancy for a few days after passing the Sun.

Among the great comets of very recent years may be mentioned those of 1858, 1862 and 1882. Few, if any,

comets have been seen in modern times surpassing in interest the great one of 1882. It was so bright as to be visible in the day time when near the Sun. It appears to have passed that luminary only about 300,000 miles from its surface. Its period of revolution is nearly 800 years.

The comet of 1744 had 6 tails; and Biela's comet divided into two, both visible in the same telescopic field of vision and each having coma, nucleus, and tail.

Meteors, aerolites, or shooting stars were regarded with wonder and superstitious awe in ancient times, and it is related that meteoric stones have been preserved in churches and temples as religious relics. One is mentioned by Pliny, which fell in 467 B. C., in Thrace; the size of a wagon. In 1492, one fell in Alsace, weighing 260 lbs., which is still preserved in the church of Ensisheim. At Mecca, is the "black stone" which is believed to have been brought from heaven by angels. It is about 7 inches in diameter, and Burton says it appeared to him like a common aerolite. It is worn smooth by the lips of the worshippers who have reverently kissed it. There was a shower of stones in Crema in 1511; 1200 pieces were collected.

On April 26, 1803, at Aigle, in France, a number of stones fell, the largest weighing 20 lbs. There have been hundreds of authentic cases recorded. A meteoric stone in the Smithsonian institution weighs 1,400 lbs. May 10, 1879 there was a meteoric fall at Esterville, Emmet county, Iowa. A fragment penetrated the ground 14 feet. A number of pieces were found; one weighed 431 pounds, another 170 pounds, and all that were found made 640 lbs.

Hundreds escape from the Earth's attraction and pass on their course. Kepler was right when he thought

interplanetary space as full of comets and meteors as the ocean with fish. Meteoric stones differ very much : some are stony, some metallic and some mixed. Iron, nickel, silicon, tin, and, in all, some twenty-two elements have been found in them.

Any clear night meteors may be seen, most of them so small that the heat developed in passing through the atmosphere burns them up while still high in the air. There are a few larger ones, but, generally speaking, they are mere particles of meteoric dust.

There are several known periodic meteoric streams that the Earth passes through in its yearly course. One encountered on the 14th of November each year gives a fine display of meteors. These November meteors are called Leonids because they radiate from the constellation Leo. In a period of about thirty-three years,—Nov. 13th to 15th, 1833 and 1866, there have been magnificent displays of meteoric showers. It has been found that the meteors travel, unevenly distributed, in an orbit around the Sun ; and the important fact has been announced that the orbit substantially coincides with that of a known comet. Thus every year the Earth comes in contact with this stream of cometary matter, and with like individual meteors constantly. There are many other meteoric periods. About August 10th, meteoric streams connected with Comet II, 1862 ; November 27th to 29th in the path of Biela's comet ; April 20th, Lyrids, from the constellation Lyra are seen. There are now more than 100 meteor systems, named from their radiation points. There are more in August than in any other month. The number, though great, visible in a year from any given point, is but a small portion of what could be seen from every part of the Earth, land and sea ; and they fall just the same whether

hidden from sight by clouds or the brightness of the Sun, or where there are no eyes to see. Their numbers are simply incomprehensible; even those that come within the Earth's attraction. Then how vast the numbers contained in the space once filled by the solar nebula, to say nothing of interspellar space.

The Zodiacal Light is a triangular track of light seen after sunset and before sunrise, stretching up from the horizon near the Sun, and extending upward of 50 degrees. Its axis corresponds with the ecliptic. It fades away at each side and toward the Zenith. There have been several theories advanced to account for it; one that it is a solar atmosphere, and another that it is a ring around the Earth; although plausible, both theories encounter fatal objections.

The theory generally adopted by astronomers is that of Laplace, the originator of the nebular hypothesis. "If in the zones abandoned by the atmosphere of the Sun there should be any molecules too volatile to be united to each other or to the planets, they ought, in continuing to circulate around this star, to offer all the appearances of the zodiacal light without opposing any sensible resistance to the different bodies of the solar system, either on the account of their extreme rarity, or because their motion is nearly the same as that of the planets with which they come in contact."

All the conditions seem to be met by supposing the zodiacal light to be caused by a multitude of minute meteoric bodies traveling in elliptical orbits around the Sun. The variabilities noticed are all explained on this theory, and it also appears to be verified by the spectroscope.

The Aurora Polaris, or Borealis, nothern lights and southern lights, is undoubtedly caused by disturbances

of the Earth's magnetic and electrical conditions. These displays have an eleven-year period corresponding with the solar activity indicated by the sun-spots. The magnetic attraction of the Earth would be likely to bring within its influence clouds of impalpable meteoric dust, principally containing iron. At periods of great activity or at times of sudden restoration of equilibrium, the more volatile molecules of the dust might be repelled by the radiating energy, as in the case of the tails of comets, as they approach the Sun. If this theory is correct, the colliding meteoric particles should develop and for a brief time retain, luminosity ; in great displays where a corona is formed, this seems to take place on a large scale. It is probable that every planet and floating particle in the planetary system responds to the magnetic thrill in sympathy with the solar disturbances.

A review of the facts relating to the solar system compels the conclusion that the nebular hypothesis of Laplace as modified in some details by later discoveries, is the only rational explanation. The facts throughout are confirmatory of the correctnesss of the hypothesis.

In the planetary system, no two bodies are of the same magnitude, and they vary in size from the Sun, down to invisible atoms. There is a vast difference in mass and volume between the Sun and Jupiter ; between Jupiter and Mercury ; Mercury and the smallest minor planet or the moons of Mars, globes some ten miles in diameter ; and between these and the smaller meteorites. Yet, a molecule a thousand times smaller than a pollen grain may be, as far as orbit, sidereal period, rotation and uniformity of motion are concerned,—an independent planet. Space is well occupied with moving bodies of all grades. Many have condensed from nebulous matter,

as have the planets, while others from outside the solar system are as we have good reason to believe,—the dust of dead and disintegrated worlds. Only a moderate proportion of the diffused particles is congregated in comets, meteoric streams and zones.

We have followed the chain of evolution from nebula to star, in the general way, and came near home to study the evolution of the solar nebula through the same natural processes into a considerable number of planets and their central star. The internal mass of Jupiter still at red heat, glows through the masses of hot vapor in his atmosphere. We shall see that millions of years ago the Earth was in the same condition, and that barring accidents, millions of years hence Jupiter will become cooled and habitable. The Sun is helplessly following the same course. Jupiter has comparatively recently ceased to be a self-luminous body. Saturn, Uranus and Neptune, though cooler, are still far from being in condition to sustain life—such as we are familiar with.

There may be beyond the orbit of Neptune, planets yet undiscovered; and it would surprise no one to have the observations of Profs. Watson and Swift, of a planet or planets inside the orbit of Mercury, confirmed.

Several observers have at different times seen unknown, round bodies cross the disk of the Sun. July 21, 1896, Prof. Brooks saw a dark, round object cross in front of the moon; probably a very large meteor.

The zone of minor planets probably contains enough material to form one planet about the size of Mars, but when this space was occupied by a nebulous ring, instead of forming one large planetary body as was the case with the principal planets, probably through the effect of the attraction of the large exterior planets, numerous centers of aggregation formed. In the formation of planets as

well as hail stones, there are widely differing results, arising from slightly varying conditions.

Differences and imperfections are found among the trees of a forest, and the same, and from much the same determining causes, among the bodies in a wilderness of worlds.

In the system of Saturn eight secondary planets have been formed without a doubt in the usual manner, from nebulous rings; but there yet remain rings of probably substantially the same material, delicately balanced by the attraction of the planet and his satellites, and showing no signs of change. Perhaps the requisite conditions for assuming the globular form may never be reached, or, possibly while the reader of these lines still lives, a passing cometary-meteoric swarm may come in contact and arrest the orderly movement of the molecules of the rings, and the heat developed by the clashing particles, aid in the formation of a secondary planet before our eyes.

In no very material respect would such an injurious or beneficial occurrence differ from the fall of a mature oak before an autumn blast, scattering acorns, the germs of future beautiful groves, while at the same time bearing down many a young and vigorous tree to untimely ruin.

Meteors are drawn from their orbits and rain upon the Earth and all the other planets; they collide with each other, and where governing principles are the same, such events may occasionally take place on a larger scale among the larger cosmical bodies. In all the Universe no preventing hand is ever raised.

CHAPTER X.

THE TERRESTRIAL CRUST.

MANY millions of years ago when the Earth was a hot and liquid mass like the large planets are now, a seething mass of vapor enveloped the whole globe, cooling on the exterior, falling in places under the force of gravitation, to be again forced upward by the internal heat energies, and swept and tossed by violent storms. The rotation of the Earth was much more rapid then, than now, and the vapors as seen from Mars, lay in belts parallel with the equator like those of Jupiter.

A time was reached in the cooling process when the surface of the liquid mass began to solidify. Probably the first solid crust fields were broken up by the constant agitation, sank in the lighter fluid and remelted. Ages passed, and at last a more enduring crust was formed upon the thickening liquid, and the pent up vapors found vent through numerous fissures. The struggle between the cold without and the heat within, went on. The cooled and condensed vapors fell in continual showers, only to be instantly again converted into steam.

The attraction of the Moon, then nearer the Earth than at present, caused bodily tides that rent and displaced the rising and falling crust. Overflowing matter solidified and strengthened it for the next tidal wave to break. It was a long and tedious process before the crust became cool enough for the rain to gain upon the evaporation and allow pools and little lakes to form.

The heavier liquids gravitated to the center of the planet, and the crust formed from the lighter surface strata. The crust, broken by escaping gases, and rent by tides and currents would be filled with pores and cavities like lava or bread. Such cellular rock would not sink to any considerable depth. Although the center of the planet would be a dense liquid, or possibly solid nucleus, there would be and remain for an enormous period, between that and the surface crust, a great depth of matter still in the liquid state.

As we descend in mines and wells, it is found that the temperature averages about one degree higher for every fifty-three feet of descent. Most rocks would be fused at the temperature given us by this rate of increase at a depth of twenty or thirty miles. Since the fusing point is higher under pressure, it follows that the crust must be thicker than these figures indicate. The peculiar motions caused by earthquakes, and volcanic eruptions of lava, are sufficient to convince common people that the crust we dwell upon is none too thick ; in fact, a greater degree of stability would not be objectionable. Even 50 or 100 miles would be a thin stratum compared with the diameter of the earth.

Many facts go to prove that the crust is falling in places, rising in others, wrinkling, cracking, and generally becoming adjusted to the gradually decreasing volume of the cooling and shrinking interior. That the contents of the interior of the Earth are in large part liquid, and at a high temperature, is not seriously questioned.

The space at our disposal will no more than suffice for a too brief outline of the interesting subjects connected with the history of the Earth's crust. I earnestly recommend the readers who have not already done so, to obtain

some late, standard work, devoted exclusively to geology, and make comparisons with their own observations. The busy man could find time, that perhaps he now wastes; there are evenings in plenty, and fifty-two Sundays in a year. Five hundred full days of Sundays in ten years, if well improved, would enable a man of average mental capacity to store up a large fund of useful scientific knowledge, that would draw the teeth and dull the claws of supernaturalism. Try it.

Several scores of millions of years ago, when these primary changes were taking place, the length of the day, as has been shown by calculations, must have been less than a quarter of what it is now, and the Moon was only some 25,000 miles from the Earth. The time of rotation of the Earth and the distance of the Moon have gradually lengthened under the influence of tidal action, as has been shown by George Darwin. All this must be considered in imagining the then prevailing conditions.

After the crust had become permanent, it remained for ages at red-heat, and the atmosphere was charged not only with aqueous vapor, but with many of the more volatile and gaseous elements. The first lakes were formed of boiling saturated solutions. Chemical changes were going on, and in the direction of the more complex, as it had ever been during the evolution from the nebula.

It is not probable that any portion of this original crust is now exposed, or in any way accessible to geologists. It does not matter, for the changes wrought by the action of the various forces would have prevented recognition.

The crust has continued to increase in thickness by crystalizations upon the interior surface from the cooling liquid mass, from matter ejected by volcanic action, and from the fall of meteors and meteoric dust from the region outside our atmosphere. If the rocks lay undisturb-

ed in their original positions, men could only examine the surface and the few hundreds of feet reached in mines and borings, but the upheavals have left them inclined at all angles, from horizontal to perpendicular. It is estimated that geologists have found and examined in different places strata of rocks with edges thus brought to the surface, equivalent to fourteen miles in thickness of the terrestrial crust. From their positions and surroundings, by numerous comparisons, their order of succession has been determined.

During the last half of the closing century this great book of nature, a true revelation of the rocks, a record of the Earth's history engraved in stone, has been well and carefully thumbed. In this enduring record, not made by human hands, containing no ambiguous manuscripts of uncertain authenticity, many lessons have been learned that will continue to influence thought, through all the generations.

For the sake of convenience, geologists have made five main divisions or eras of the geological record and the geological time :—(1) Archæan ; (2) Palæozoic ; (3) Mesozoic ; (4) Cenozoic, or Tertiary ; and (5) Quaternary, or Post-tertiary and Recent. Each of these main divisions is further subdivided into periods or systems, and the periods into formations.

The Archæan are the oldest known rocks, and constitute the first chapter of the history of the Earth as preserved to us. As they now are they offer no evidence of having once been a part of the original crust. Considering the changes wrought by heat, pressure, and the action of the elements, during probably not less than 100,000,000 years, it would not be expected that original features would be retained.

The rocks of the Archæan era pass below into the gran-

ite, and consist largely of gneiss, have a stratified character, are of great extent and thickness, and represent well toward half of the time passed since they began to form. They were made up of the debris of the earlier rocks, worn down by rains, streams, tides, winds, changes of temperature, chemical action, etc., and deposited as sediment in the ocean. In time they were elevated as other portions of the globe were depressed, and became dry land; and the sediment dried and hardened into solid rock. All geological changes, or nearly all, are brought about slowly, and by these steadily acting natural causes, and require vast periods of time.

The strata embraced in the Archæan, includes the Laurentian system, which in Canada is estimated to be 50,000 feet thick. Large quantities of iron are found in these strata. The internal heat of the Earth has metamorphosed this mass of rocks, and burned out or altered beyond recognition the organic remains it doubtless once contained.

It was in the great period during which these strata were being deposited, that life must have originated upon the Earth; unless, indeed, it began in a preceding age. Along the shores and lagoons, and amid the deposits and chemical changes of the warm primeval ocean, conditions were more favorable than at any later period for the formation of colloid compounds, and protoplasm; "The living matter from which all kinds of living beings are formed and developed, and to the properties of which all their functions are ultimately referred." The step was comparatively short from unstable, jelly-like chemical compounds with gently active properties, to the unstable jelly-like chemical combination known as protoplasm, that displays, as in the Amœba, slowly and faintly, the properties of motion, and dawning sen-

sation, or as in the Desmid assimilation without apparent sensation. In many instances, under the highest and best powers of the microscope living protoplasm does not show structure, but is to all appearance without organization. In other specimens simple structural indications are noted. If we yet have living protoplasm near the dividing line, it would be presumptuous to deny the existence of still more simple living matter in the first lagoons, differing but slightly from its sister non-vital substances. We are considering two slightly different forms of matter, possessing as properties two slightly differing forms of energy,—one of which is known to us as vital force.

There has been found in the Laurentian rock a peculiar structure that has led to a long discussion and much difference of opinion among geologists. One side, and among them are some very able microscopists, contends that the Eozoon Canadense, as it has been named, was an almost formless, branching, chambered, protoplasmic animal mass that grew on the ancient ocean bottom, and secreted a protecting coat of lime, that now forms the walls between the tubes or chambers. This view is rendered more probable by the presence in that early age of iron-ore, graphite and lime, almost sure evidence of the existence of living organisms. Coal is of vegetable origin and its metamorphism produces graphite. The more recent lime formations are composed almost wholly of the shells of lower animals. Again, the Eozoon Canadense is a primitive form such as could have been expected to flourish in that early age. There are other geologists, perhaps equally competent, who, admitting that this object has some peculiarities of structure, yet it so closely resembles some known mineral formations, they consider the proof of its animal

origin insufficient. The controversy in itself might be taken as evidence that it helps to bridge any alleged gap between the highest mineral and lowest organic forms.

The vast amount of sedimentary rock found, indicates a like amount of other rock ground up and disintegrated into mud and washed into the ocean. This process being constantly going on, it follows that the same material has gone through these changes many times. Rock, when elevated to the surface, becomes subject to erosion. In any locality there will be many long gaps in the geological record—for fossils are destroyed with the strata. Such a gap intervened between the Archæan system and the Palæozoic, and it was of great duration. Future discoveries will doubtless help to connect the history by filling up this vacant place as others have been filled in the past.

It is not likely that any remains of the first living organisms will ever be found ; they were simply naked protoplasm, without any hard parts capable of permanent preservation in a fossil state.

The Palæozoic era is also called the Silurian Age or age of invertebrates. The processes of evolution had been going on in the long interval, and the newer age opened with more highly developed animals and plants.

The many thousands of feet of strata were formed of sediment deposited in shallow water,—and of course during a long continued gradual subsidence of the areas covered. During the earlier part of the era the highest animal life that appeared is represented by chambered shells, and in the later period, the lowest forms of vertebrates appeared.

The Palæozoic rocks are divided into the Silurian,